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THE RECOVERY OF POTASH FROM ALUNITE.

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INTRODUCTION.

The scarcity of potassium salts in this country due to disturbed conditions abroad, coupled with the discovery of extensive deposits of high-grade alunite [1] in central Utah, have caused considerable development work in this field and greatly stimulated interest in processes for the extraction of potash from this mineral.

Alunite, even when fairly pure, must be regarded as a relatively low-grade potash carrier, and since the more important deposits occur in a region far from the fertilizer market, any process employed for the extraction of potash from the mineral must be not only highly efficient but extremely cheap. Indeed, under normal conditions it is unlikely that any method will prove commercially practicable for exploiting the Western alunites which does not produce in addition to a soluble potash salt, some other salable product.

Experience in the handling of low-grade ores, or in operations for the extraction of a moderate-priced product from any raw material, has shown that strict attention to details and a knowledge of their importance will often mean the difference between profit and loss.

It was with a view to determining the importance of such details in the recovery of potash from alunite that the work described in this paper was undertaken.

[1] Butler and Gale, Bull. 511, U. S. Geological Survey (1912). Loughlin, G. F., Bull. 620-K, U. S. Geological Survey (1915).

COMPOSITION AND PROPERTIES OF ALUNITE.

Alunite is a hydrous sulphate of potash and alumina which may be represented by the following formula:

$$K_2O.3Al_2O_3.4SO_3.6H_2O.$$

The percentage composition of the pure mineral, according to Dana,[1] is as follows:

	Per cent.
SO_3	=38. 60
Al_2O_3	=37. 00
K_2O	=11. 40
H_2O	=13. 00

The mineral usually occurs as a massive, fine-grained, pinkish-white rock breaking with a conchoidal fracture. Some of the coarser varieties are distinctly crystalline in character. While theoretically it should contain over 11 per cent of potash, it is seldom found in minable quantities running over 9.5 or 10 per cent in potash. It is frequently contaminated with quartz and the silicates of potash from which it is derived. The mineral is insoluble in water, but soluble in strong sulphuric acid. On heating to a moderate temperature (500° C.) water is driven off and the mineral decomposes into alumina and potassium aluminum sulphate.[2] Upon increasing the temperature (to 700° to 750° C.) the latter compound is decomposed, fumes of sulphur dioxide and trioxide are evolved, and a residue remains which consists of alumina and soluble potassium sulphate.

GEOLOGICAL OCCURRENCE AND ORIGIN.

Alunite forms seams in trachytic and similar rocks, being produced by the alteration of such rocks by means of sulphurous vapors or sulphate solutions. It is believed to be closely related in origin to metal veins.

Ransome[3] has discussed the various methods by which alunite deposits may be formed, and Butler and Gale[4] quote extensively from the former in their description of a deposit southwest of Marysvale, Utah. The latter authors in discussing the Marysvale alunite state that they consider the main vein in this locality a fissure filling and not a replacement of the wall rock, and cite, as proof of this theory, the fact that the alunite contains but little silica, while in the wall rock where replacement has taken place quartz phenocrysts remain practically unaltered. They conclude that the mineral vein was introduced in part at least by solutions of deep-seated origin.

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[1] System of Mineralogy.

[2] As a matter of fact it is very difficult to drive off the water of constitution without also driving off some of the oxides of sulphur.

[3] Prof. Paper No. 66, U. S. Geological Survey, pp. 189–195 (1899).

[4] Bull. 511, U. S. Geological Survey (1912).

The alunite described by these writers, however, is mainly the pink variety, crystalline or cryptocrystalline, coming chiefly from a large banded vein cutting the volcanic rock at a high elevation about 7 miles southwest of Marysvale. The samples of alunite used in the following experiments were a light colored variety showing little or no crystalline structure and some of it containing considerable amounts of silica. These samples came from two deposits [1] about 10 miles north of that described by Butler and Gale. One appears to be a very wide vein between two rhyolite dikes. The other has the appearance of an enormous outcrop, one wall of rhyolite well defined. The geological features, however, have not as yet been worked out in detail.

LOCATION, EXTENT, AND ACCESSIBILITY OF THE UTAH ALUNITES.

While a number of occurrences of alunite of minor importance have been reported [2] by the United States Geological Survey, the most important deposits described [3] are those occurring in the Tuscar mountain range at the head of Little Cottonwood Canyon from 7 to 8 miles southwest of Marysvale, Piute County, Utah. (See fig. 1.)

The lower end of this deposit is fully 4,000 feet above Marysvale, the present terminus of the San Pete Branch of the Denver & Rio Grande Railroad. This branch connects with the main line of the Denver & Rio Grande at Thistle, about 100 miles north of Marysvale.

Butler and Gale have estimated the amount of high-grade alunite in one group of claims (to a depth of 100 feet) at 300,000 tons. Loughlin [4] in a later examination of some other properties in this region increased this estimate of high-grade alunite to 474,900 tons.

About 2 miles north of Marysvale begins the Sevier Canyon. The Sevier River runs between steep and often sheer banks rising from a few feet to several hundred, the banks being backed by mountains rising in some cases as high as 2,000 feet above the river bed. The canyon is about 14 miles long and on both sides for a distance of 8 or 10 miles north of Marysvale and a distance of 3 or 4 miles on each side of the river it has been very actively if not thoroughly prospected for alunite, a great many locations having been made within the last two years. Some fine masses of the typical pink or pinkish cryptocrystalline varieties have been found, though usually these are so located as to make their exploitation difficult. But a large area of light-colored material has also been discovered, some of which is of

[1] The geological data and geographical location of the deposits of light-colored alunite were furnished by Dr. F. K. Cameron, formerly of this bureau, to whom the writers are also indebted for a number of valuable suggestions.

[2] Phalen, W. C., Mineral Resources, pp. 9–33, U. S. Geol. Survey (1913).

[3] Butler and Gale, Bull. 511, U. S. Geological Survey (1912). Loughlin, G. F., Bull. 620-K, U. S. Geological Survey (1915).

[4] Bull. 620-K U. S. Geological Survey (1915).

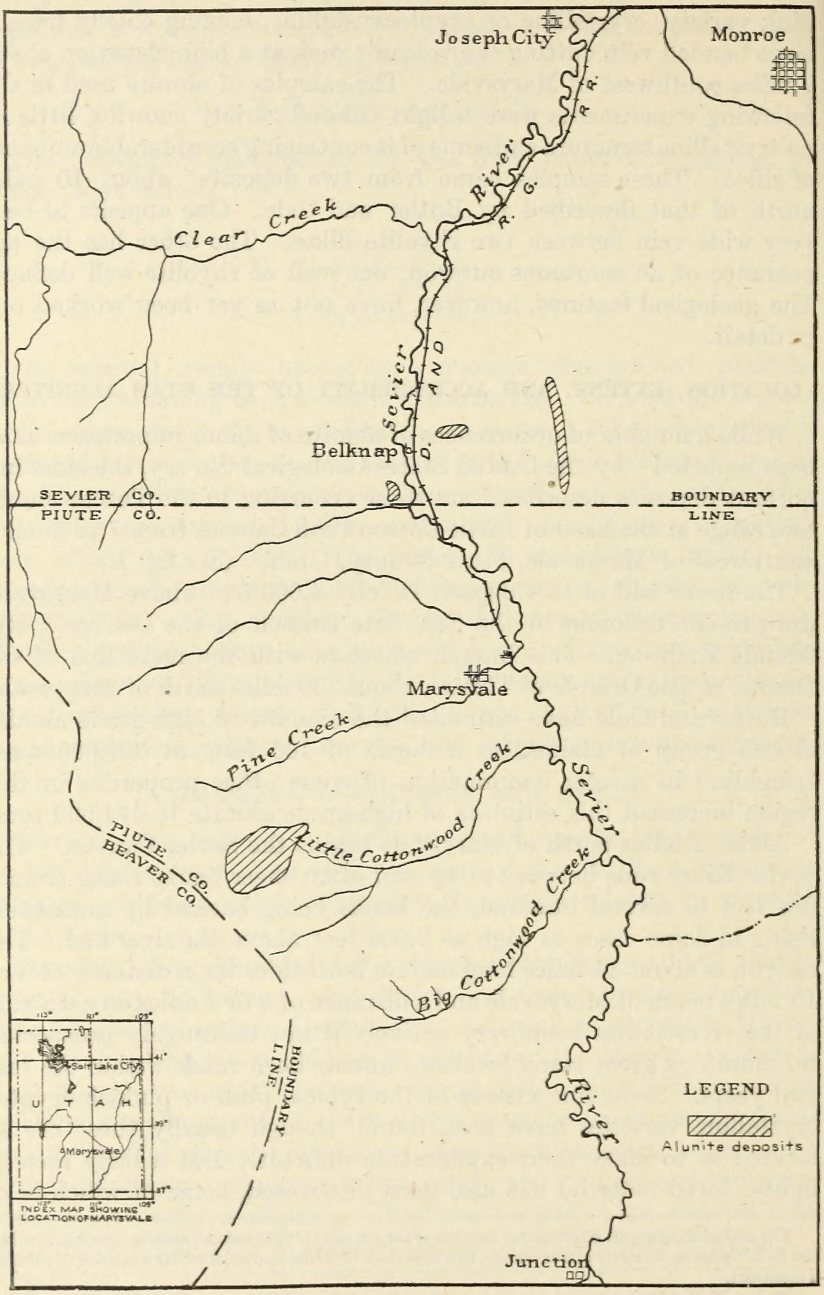

FIG. 1.—Sketch map showing location of alunite deposits near Marysvale Utah.

good grade, and should increase considerably the supply of commercial alunite in sight.

Another important deposit occurs between 4 and 7 miles north of Marysvale and about 3 miles from the river and the station of Belknap, on the Denver and Rio Grande Railroad. The alunite lies between two rhyolite dikes running almost due south from Twin Peaks (better known locally as Peak St. Louis or Iron Mountain) to a peak (Santa Cruz claims) just north of the dividing line between Sevier and Piute Counties. There is a fairly good wagon road from Iron Mountain to Belknap. The alunite mass between these two dikes is from 1,200 to 1,500 feet wide and about 4,000 yards long. While no measurements have actually been made, the depth of the deposit is probably considerable.

These alunite deposits occur at a much lower level and are more readily accessible than the purer crystalline deposits southwest of Marysvale and should be mined and shipped very cheaply.

THE PRODUCTION OF ALUM FROM ALUNITE.

The main commercial use of alunite heretofore has been in the manufacture of potash alum. This industry was introduced into Europe as early as the thirteenth century and assumed considerable prominence at Tolfa, Italy, where extensive deposits of alunite occur. Alum is still produced in this region by the following process:

The mineral is calcined at low red heat in heaps or in kilns for about 6 hours. When the oxides of sulphur begin to escape the material is removed and transferred to brick bins, where it is exposed to the air for several weeks or months, being moistened with water from time to time during that period. The product is then mixed with water and after the insoluble material has settled the clear solution is decanted, evaporated, and crystallized. The reactions taking place on heating to 500° C. may be represented thus:

1. Alunite. $K_2O.3Al_2O_3.4SO_3.6H_2O =$ Potass. aluminum sulphate. $2KAl(SO_4)_2$ + Alumina. $2Al_2O_3$ + Water. $6H_2O$

2. Potass. aluminum sulphate. $2KAl(SO_4)_2$ + Water. $24H_2O =$ Potash alum. $2KAl(SO_4)_2\ 24H_2O$

Another method of producing potash alum from alunite, as recommended by Guyot[1] consists in heating the mineral to 800 C.° for

[1] Sur la richesse industrielle de l'alunite cone en poudre. Compt. Rend. Acad. Sci. Paris, *95* pp. 693-694; Experiences sur la calcinations de l'alunite en poudre. Idem. p. 1001-1003.

three hours. The ignited mass is then treated with the proper quantity of sulphuric acid (30° B.) to convert the alumina present into sulphate. After standing for some time an amount of potassium sulphate is added sufficient to convert the aluminum sulphate into the double salt. The clear liquid is then decanted off and evaporated until the potash alum crystallizes out. The reactions on heating to 800° C. may be represented thus:

1. Alunite.
$K_2O.3Al_2O_3.4SO_3.6H_2O =$
Potassium sulphate. Alumina. Sulphur trioxide. Water.
$K_2SO_4 + 3Al_2O_3 + 3SO_3 + 6H_2O$

2. Alumina. Sulphuric acid. Aluminum sulphate. Water.
$3Al_2O_3 + 9H_2SO_4 = 3Al_2(SO_4)_3 + 9H_2O$

3. Aluminum sulphate. Potassium sulphate. Water.
$3Al_2(SO_4)_3 + 3K_2SO_4 + 144H_2O =$
Potash alum.
$6\,KAl(SO_4)_2\,24H_2O$

In the production of alum from the alunite occurring at Bullah Delah, Australia,[1] a process similar to that just described is practiced, but no particular temperature of ignition is specified and the excess of alumina is not converted into alum by the addition of potassium sulphate, since it is considered more profitable to manufacture aluminum sulphate as a by-product and to produce alum equivalent only to the potash present in the alunite. This practice is no doubt the best in localities far removed from other sources of potash.

While it was not the purpose of the present investigation to study details of alum manufacture, it would seem that in regions where another source of potash is readily and cheaply available a combination of the two processes outlined above promises greater possibilities than either of the methods employed at present.

In brief, it is thought that the ignition of alunite at a moderate temperature (500° to 550° C.) and subsequent treatment with sulphuric acid and potassium sulphate would mean a saving both in fuel and in the quantity of acid required to convert all the alumina of the mineral into alum.

THE PRODUCTION OF POTASH FROM ALUNITE.

Besides the processes just outlined for the production of alum six general schemes have been proposed for the utilization of the potash in alunite for other purposes.

[1] Pittman, E. P. Alunite in New South Wales. Report Geol. Survey New South Wales (1901).

The first of these is the use of the material after ignition at 750° to 800° C. directly as a fertilizer without effecting a separation of the soluble potash salt. It has been pointed out by one of the writers [1] that the material after ignition compares very favorably in regard to its potash content with "manure salt" or other low-grade potash carriers heretofore imported from Germany. If produced in the West, however, it is unlikely that such a low-grade product could stand the cost of the long rail haul necessary to bring it to the fertilizer market. Moreover, no salable by-product would be obtained, except perhaps sulphuric acid, which would require expensive equipment to collect and which under normal conditions has a very restricted market in the West.

The second scheme [2] is to ignite the material at 800° to 1,000° C. till the sulphate of aluminum is decomposed and then leach the residue with hot water to dissolve out the potassium sulphate, which is later recovered by evaporation of the solution. In the case of the purer alunites the residue consists largely of aluminum oxide suitable for the manufacture of metallic aluminum. This method has attracted considerable attention, and it is understood that a procedure similar to, if not identical with, it is being practiced in the western alunite fields. Difficulty in obtaining complete extraction of the potash in the ignited alunite has been experienced both in the laboratory [1] and on a commercial scale, and it was partly with a view to studying the causes of this incomplete recovery of the potash that the experiments described further on were conducted.

The third process [3] consists in roasting alunite with lime at 1,200° to 1,800° F., producing thereby sulphate of lime (gypsum) and potassium sulphate, and rendering the alumina insoluble. The potassium sulphate is then extracted with water. The main purpose of this process is to produce potassium sulphate without causing the evolution of objectionable or injurious fumes of sulphur dioxide and trioxide.

The cost of the lime required, the conversion of the sulphuric acid into a relatively valueless form, and finally the difficulty of separating the resulting gypsum from both the potash and the alumina, render this process of rather doubtful value. As far as is known this process is not at present being employed for the manufacture of potash from alunite.

The fourth [4] process consists in first calcining the alunite to drive off the oxides of sulphur and the water and then increasing the temperature to between 1,100° and 1,600° C., thus volatilizing the

[1] Circular 70, Bureau of Soils, U. S. Dept. Agr. (1912).
[2] Chappell, H. F., U. S. Patent No. 1070324 (1913).
[3] Morgan, Geo. S., U. S. Patent 1161239 (1915).
[4] MacDowell, C. H., U. S. Patent No. 1136549 (1915).

potassium sulphate and collecting it in some suitable manner. It is claimed that the addition of carbon to the mineral during ignition facilitates the volatilization of the potash, causing it to take place at a much lower temperature than that specified above. The residue, it is said, is suitable for the manufacture of metallic aluminum.

Potash is now being recovered as a by-product from blast-furnace operations and in the manufacture of cement from potash-bearing silicates, lime being used to convert the potash into oxide, in which form it is readily driven off. The residue then consists of a clinker having the composition and properties of hydraulic cement, a readily salable product.

While the volatilization process may be applicable to the purer grades of alunite, it seems likely that a fixation and consequent loss of potash would ensue if this practice were applied to alunite high in silica. The addition of coal or coke to the charge, as recommended by the inventor of this process, would also tend to decrease the value of the residue remaining in the furnace.

In order to avoid the difficulty of obtaining a complete extraction of the potash from highly heated alunite, and also for the purpose of obtaining alumina in a pure form suitable for the manufacture of metallic aluminum, Cameron [1] has proposed a process, the first steps of which are similar to the old method of making potash alum. The mineral is first ignited at a relatively low temperature (500° to 550° C.) sufficient only to decompose it into alumina and the double salt potassium aluminum sulphate. The latter compound, which is much more soluble than potassium sulphate, is leached out with water, and alum is crystallized from the resulting solution. The alum is then heated till it decomposes, yielding pure alumina and potassium sulphate, which are separated by solution of the latter. The fumes of sulphur dioxide and trioxide evolved during the decomposition of the alum are conducted into a suspension of the alumina from the first ignition, forming aluminum sulphate and sulphite. The salts in solution are then filtered free from any insoluble residue and either sold directly as precipitants or mordants, or they are evaporated to dryness and ignited to produce more alumina.

Another method of treating alunite has been the subject of a public-service patent application by Mr. Paul J. Fox, of this bureau. In this process the aim is to separate the potassium as sulphate and leave the aluminum as fluoride in a condition suitable for recovery by electrolysis. The sulphuric acid is not recovered. Alunite and fluorspar or some other fluoride are powdered and intimately mixed (or, better, are ground together) and heated at such a temperature that the hydrofluoric acid (of the fluoride) is set free by the sulphuric acid (or sulphur trioxide) yielded by the alunite on heating. The

[1] An application for a patent on this process has been filed by the inventor.

author states that this converts the alumina into aluminum fluoride, the potassium remaining as sulphate. The product is then leached, the potassium dissolving as sulphate, and the aluminum remaining in the residue in large part as fluoride. Considerable calcium sulphate remains with the aluminum fluoride, which might necessitate changes in the standard process for the electrolytic recovery of aluminum.

TEMPERATURE OF IGNITION AND ITS EFFECT ON THE SUBSEQUENT LEACHING OF ALUNITE.

Of the methods so far proposed for the production of potash from alunite, those which depend on simple ignition and subsequent extraction of the soluble potash with water appear to the writers most attractive.

The following investigation was conducted for the purpose of determining the best conditions under which a complete extraction of the potash could be made from impure as well as the purer grades of alunite, with due regard to the production of a salable by-product. The investigation involved the study of the effect of ignition at various temperatures, as well as the influence of fineness of division on the solubility, or, more correctly speaking, the ease with which the mineral yields its potash to hot water.

Chappell,[1] in discussing the ignition of and subsequent extraction of potash from alunite, states that the temperature may be carried over 1,000° C. without causing the formation of potassium aluminate, and recommends a temperature of from 800° to 1,000° C. for alunites containing from 1 to 2 per cent of silica. The experience of the writers has been, as shown below, that in igniting alunite containing even small quantities of silica, 800° C. should be the maximum temperature allowed in the furnace.

Eleven samples of light-colored alunite from the deposits north of Marysvale, Utah, were employed in these experiments. Most of the samples were ground to pass a 100-mesh sieve, though it was later shown that this was probably unnecessary. The material ranged in potash content from 3.48 to 9.61 per cent and in silica from 1.67 to 39.93 per cent.

The potash content of the samples was determined by the J. Lawrence Smith method,[2] and silica and alumina were also determined in all the samples. The results of these analyses are given in Table I.

[1] U. S. Patent No. 1070324 (1913).

[2] In order to avoid an excess of sulphates, the samples after being weighed out were ignited at a bright red heat before mixing with the ammonium chloride-calcium carbonate mixture.

TABLE I.—*Analyses of samples of light-colored alunite from the Marysvale area, Utah.*

Sample number.	Silica (SiO_2).	Iron and aluminum oxides. (Fe_2O_3, Al_2O_3).	Potash (K_2O).	Sample number.	Silica (SiO_2).	Iron and aluminum oxides (Fe_2O_3, Al_2O_3).	Potash (K_2O).
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	4.41	36.10	9.61	7	39.93	23.17	5.64
2	16.98	35.96	6.13	8	1.67	37.38	8.60
3*b*	16.66	34.30	7.24	9	35.93	25.82	4.30
4	29.14	27.06	6.89	10	39.20	26.97	3.48
5	27.50	28.49	6.13	11	22.08	30.16	6.41
6	5.90	36.71	8.20				

Two-gram samples of each alunite were then heated in an electric muffle furnace for a little over an hour at from 550° to 650° C. and from 850° to 950° C. Four samples (Nos. 1, 2, 5, and 6) were heated to a temperature midway between these two extremes, namely, 750° to 775° C.

The loss on ignition was determined and the residues then washed on the filters with small successive quantities of hot distilled water till the washings gave practically no test for sulphates. The filtrates were then analyzed for potash and the efficiency of the extraction thus determined. The results of these experiments are given in Table II.

TABLE II.—*Loss on ignition and percentage of potash extracted from alunite after heating at various temperatures.*

Sample number.	Loss on ignition at—			Proportion of total K_2O extracted with water after ignition at—		
	550° to 650° C.	750° to 775° C.	850° to 950° C.	550° to 650° C.	750° to 775° C.	850° to 950° C.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	14.50	37.71	39.55	98.44	100.00	89.49
2	20.30	32.37	35.81	97.23	94.78	35.90
3*b*	21.71	.....	35.35	93.64	.....	59.95
4	15.01	.....	29.43	99.28	.....	85.20
5	12.44	28.37	31.04	84.99	87.28	54.97
6	22.18	37.55	39.09	91.30	100.00	92.17
7	14.18	.....	26.41	94.15	.....	55.69
8	16.13	.....	41.93	[1]	.....	92.44
9	14.26	.....	28.55	64.89	.....	39.77
10	14.54	.....	26.86	[2] 58.62	.....	9.50
11	16.71	.....	33.00	73.17	.....	72.08

[1] Determination lost.
[2] Traces of feldspathic material found in this sample by Mr. W. H. Fry probably explain the low yields of potash on leaching.

A study of Table II will show that the extraction of potash by water from the alunite heated at a relatively low temperature (550° to 650° C.) was much more complete than from those samples heated to 850° C. or above. By referring to Table I it will be seen that the low yield of potash obtained from the highly heated mineral was

especially marked in the case of the samples containing large percentages of silica, indicating that at high temperatures a fixation of the soluble potash takes place in the presence of this substance. The leached residues from the highly heated samples, 3*b*, 7, and 10, were, therefore, submitted for a microscopic examination by Mr. W. H. Fry, of this bureau, but owing to the amorphous nature of the material no compounds of silica and potash could be identified.

It is possible also that there might be a loss of potash through volatilization, but analyses of the leached residues 2 and 5 showed there had been no such loss.

In order to leach the highly heated samples free from sulphates only 75 c. c. to 115 c. c. of hot water were required, while the samples heated to 550° to 650° C. required from 280 to 400 c. c. of water. The difficulty in extracting the sulphates in the latter case was due in part no doubt to the gelatinous nature of the residue and partly also to the greater quantities of basic sulphates present. The filtrates from these latter residues were quite cloudy on account of the separation of basic aluminum sulphate, and upon the addition of ammonia considerable alumina was precipitated. The filtrates from the highly heated samples, on the other hand, were only slightly cloudy and contained but very little alumina, showing that the decomposition of the double salt potassium aluminum sulphate was practically complete.

The four samples of alunite (Nos. 1, 2, 5, and 6) which were heated from 750° to 775° C., a temperature only slightly above that at which complete decomposition of alunite takes place,[1] yielded up their potash quite readily, less than 100 c. c. of hot water being required to wash the residues free from sulphates. Moreover, the extraction of potash was more complete than from the same samples heated at either a higher or lower temperature. The filtrates were somewhat opalescent, but gave only a slight precipitate with ammonia, showing that the decomposition of the double salt potassium aluminum sulphate was almost complete.

INFLUENCE OF FINE GRINDING ON THE EXTRACTION OF POTASH FROM ALUNITE.

In factory practice material may be ground so that 80 to 90 per cent will pass a 60-mesh sieve at comparatively small cost, but the grinding of relatively hard rock to a greater degree of fineness than the above not only consumes considerably more time but also increases appreciably the cost of production.

In the extraction of potash from alunite the question has been raised as to the degree of fineness to which the material should be

[1] Circular 70, Bureau of Soils, U. S. Dept. Agr. (1912).

reduced before ignition in order that substantially all of the potash might be subsequently extracted with water. The following experiment was conducted to test this point:

A sample of high-grade alunite containing 10.56 per cent total potash (K_2O) was ground to three different degrees of fineness as follows: 60 to 100 mesh, 100 to 180 mesh, and 180 mesh and finer. Analyses of the separates showed that there was practically no segregation of potash in either the coarse or fine material.

Two-gram samples of each of the separates were weighed out, ignited at 750° to 775° C. for 1 hour, extracted with water, and the potash determined in the filtrates as before. The results of this experiment are given in Table III.

TABLE III.—*Extraction of potash with hot water from a sample of alunite ground to three different degrees of fineness and ignited at from 750° to 775° C. for over 1 hour.*

Sample number.	Degree of fineness.	Total K_2O.	Amount K_2O extracted.	Proportion of total K_2O present.	Amount of water required for extraction.
	Mesh.	*Per cent.*	*Per cent.*	*Per cent.*	
12*a*	60 to 100	10.56	10.25	97.06	160
12*b*	100 to 180	10.56	10.45	98.96	160
12*c*	180 and finer.	10.56	10.33	97.86	227

The figures given in Table III show pretty conclusively that nothing is to be gained by grinding relatively pure alunite finer than 60 mesh before ignition. In fact it was found that the coarser samples decrepitated on ignition to such an extent that three-fourths or more of the residue would pass a 180-mesh sieve.

ECONOMIC CONSIDERATIONS.

While it was not the purpose of the present investigation to enter into details of the cost of separating the several products from alunite, it is thought that a short discussion of some of its economic features together with a brief consideration of the value of the various products and the estimated cost of producing them will prove of interest.

In the extraction of metals from ores or in the manipulation of any raw material occurring far from the market for the product sought it is usually considered better economic practice to concentrate or carry out the necessary manufacturing processes at a point as near as practicable to the source of the raw materials, thus avoiding the cost of shipment on valueless gangue or industrial waste.

In case of the relatively pure alunites of south-central Utah, however, it seems to the writer that the advantage lies the other way, since practically all of the ingredients of alunite (with the exception

of the water) have a commercial value in the east, where better facilities for their separation are to be had and whither the mineral may be shipped at the lower rates usually prevailing for raw materials. Probably factories in the Middle West are most favorably situated for the handling of the raw material.

The ignition of the mineral could probably be very economically carried on at one of the sulphuric-acid plants run in connection with the fertilizer factories. The oxides of sulphur evolved during the burning of ore could be turned into the Glover tower of the acid plant and the yield of acid substantially increased at very little cost. Moreover, the potassium sulphate produced could be consumed on the spot in the manufacture of mixed fertilizers.

In Table IV are given the quantities and value (under normal conditions) of the ingredients of alunite (90 per cent pure) and in Table V the estimated cost of separating and preparing these products for the market.

TABLE IV.—*Amount and value (under normal conditions) of products contained in 1 ton (2,000 pounds) of alunite (90 per cent pure).*

	Dollars.
K_2O, 198 pounds, at 4 cents per pound	7. 92
H_2SO_4 (50° B.), 1,647 pounds, at $6 per ton [1]	3. 44
Al_2O_3, 666 pounds, at $7 per ton [2]	2. 33
Total value	13. 69

TABLE V.—*Estimated cost of mining, shipping, and extracting the products of alunite.*

	Dollars.
Mining per ton	1. 00
Freight to Mississippi River, per ton [3]	9. 00
Cost of grinding, per ton	. 30
Cost of ignition, per ton	. 50
Cost of acid recovery, per ton	1. 00
Cost of leaching and recovering potash	1. 00
Total cost	12. 80

From the figures given in Tables IV and V it is evident that in normal times the margin of profit on the products of alunite would be extremely narrow because of the long freight haul unless a lower freight rate should be established for the raw material. Under present conditions, however, the prices of metallic aluminum, sulphuric acid, and potash salts have advanced so enormously that the immediate exploitation of the western alunite should prove both practicable and profitable.

[1] Only three-fourths of the SO_3 of alunite is volatilized on ignition.

[2] The value of the Al_2O_3 is based on that in bauxite. The average bauxite contains 60 per cent Al_2O_3 and is valued normally at $4.75 per long ton.

[3] No commodity rate yet exists for alunite, but if a rate is established it has been estimated that it probably would be in the neighborhood of $9 per ton.

SUMMARY.

Considerable interest is being evinced in processes for the recovery of potash and other products from alunite. This mineral is a hydrous sulphate of potash and alumina. It occurs in important deposits both north and southwest of Marysvale, Utah.

Difficulty in effecting a complete separation of the potash after the ignition of the mineral has been experienced both in the laboratory and in factory practice; and since the material must be regarded as a relatively low-grade potash carrier, cheapness and efficiency in the extraction of the potash are essential to its successful commercial development.

Eleven samples of light-colored alunite from the undeveloped, but readily accessible, area north of Marysvale were ignited at different temperatures and the residues subsequently leached with water. A temperature between 750° and 800° C. was found to be best for the complete extraction of the potash with the minimum amount of water. Temperatures above 800° C. caused a fixation of the potash, particularly where the samples contained much silica.

An experiment to test the influence of fineness of grinding on the subsequent extraction of potash from alunite showed that nothing is to be gained by grinding the material finer than 60 mesh.

Since practically all of the constituents of high-grade alunite have their market in the East, it is suggested that it would prove more economical to ship the mineral East, taking advantage of the lower freight rate on raw material, than to manufacture the finished products near the mines. The freight charges, even then, however, are so great as to leave a very narrow margin of profit on the products in normal times.

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